GUIDELINES FOR MUNICIPAL WASTEWATER IRRIGATION

Alberta
ENVIRONMENT

APRIL 2000

Municipal Program Development Branch
Environmental Sciences Division
Environmental Service

Pub. No.: **T/528**
ISBN: **0-7785-1149-9 (Printed edition)**
0-7785-1150-2 (On-line edition)

Web Site: http://www.gov.ab.ca/env/

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FOREWORD

The previous guidelines on wastewater irrigation entitled, A practical guide to Municipal Wastewater Irrigation - Discussions and Guidelines[1], was first published by Alberta Environment in June, 1984. These guidelines were intended for the use of municipalities considering irrigation as a method for disposal of wastewater. After fifteen years, the focus of the program remains the same, i.e. wastewater irrigation is agriculturally beneficial and environmentally acceptable provided effective management practices are adopted and followed.

In 1996, Alberta Environment commenced a stakeholder driven process to review and revise the 1984 guidelines. The following participated in the process:

Bennett, Rod	-	Alberta Agriculture, Food and Rural Development
Chinniah, Karu	-	Alberta Environment
Forster, Jock (Chair)	-	Alberta Environment
Hecker, Frank	-	Alberta Agriculture, Food and Rural Development
Lang, Pat	-	Alberta Environment
Lutwick, Gerald	-	Alberta Environment
Sinclair, John	-	Town of Taber

Jock Forster, who chaired the stakeholder committee, took the lead role in drafting this document.

The new guideline contains the procedures that must be followed in developing and managing wastewater irrigation projects, including wastewater quality characterization, land unit suitability factors, soil and vegetation loading limitations, and various irrigation system design considerations.

EXECUTIVE SUMMARY

Municipal wastewater must be collected and treated to meet the quality standards set by Alberta Environment, before its authorized release into the environment. The treatment processes to meet the prescribed standards may vary from municipality to municipality, as they depend on the community size, influent quality, and the method of effluent disposal to the environment, i.e. whether it is discharged directly to a water body or disposed on land.

Disposal of the treated effluent on land through wastewater irrigation, while affording a unique opportunity to avoid discharges of nutrient-rich wastewater to surface waters, can also impose certain risks to public health and the environment.

Not all treated municipal wastewater meets a quality that would enable unrestricted use for irrigation. Elevated nutrient, salt, sodium, or other biological or chemical constituents are often present at concentrations that could influence the rate and/or frequency of application or restrict the type of crop to be grown. In certain cases, treated municipal wastewater has been found to contain salt or sodium levels that would completely exclude consideration of its use for irrigation due to the harmful effects it would cause to the land and the crops to be grown.

Wastewater loading is ultimately based on the consumptive water needs of the specific crop grown. This wastewater loading value, however, must also consider issues of varying rainfall, seasonal moisture deficiencies, application efficiencies, and other considerations related to leaching and crop nutrient utilization factors. The primary objectives should, therefore, be the long-term enhancement of crop production, while minimizing associated health and environmental risks.

Thus, when evaluating wastewater for irrigation use, it is important to:

- identify physical, biological, and chemical constituents that may be a potential environmental or health-based concern; and

- ensure wastewaters, considered for irrigation application, have been appropriately tested.

Other climatic, social, management, and landbase considerations that should also receive close evaluation and assessment include:

- development of appropriate protocols for determining land areas that are suitable to receive municipal wastewater for irrigation;
- determination of climatic, crop, land use, or easement restrictions that may apply;
- determination of the appropriate annual wastewater loading rates, the frequency, duration and method of application, as well as the period over which such applications can occur; and
- inclusion of a process that will ensure there is appropriate technical review of valid neighbourhood stakeholder concerns.

These above noted factors must be investigated and reported before any municipal wastewater irrigation is authorized. Guidelines are therefore necessary to facilitate such an authorization process.

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1.0 INTRODUCTION

1.1 Purpose of the Guideline

The guideline is intended for use by owners of municipal wastewater systems and consultants considering or practicing land application as a method of wastewater disposal. Some of the potential hazards and benefits associated with such applications are discussed. Factors to be considered when planning such programs are outlined. Established methods for deriving admissible rates, duration, and frequency of such applications are also provided.

The purpose of the guideline is to ensure that municipal wastewater is used for irrigation only when environmentally acceptable and agriculturally beneficial. The criteria used to describe regulatory expectation are based on previous experimental data collected by Alberta Environment, standards and requirements specified nationally in other provinces and countries, and relevant published technical information. Wastewater suitability for irrigation is based on a select set of water quality parameters to be tested prior to and during their release. Site acceptability is to be based on pertinent soil and geologic properties, topography, hydrology, climate, zoning and cropping intentions. System design considerations focus on required wastewater storage and sprinkler layout that help optimize crop moisture and nutrient use while avoiding potential undesirable issues of uneven distribution, drift, excessive leaching, or wastewater runoff from the site.

Wastewater irrigation as a municipal wastewater disposal option is an activity requiring authorization as defined in the Alberta Environmental Protection and Enhancement Act. The guideline is intended to help with the approval process, and to explain how information is interpreted to assess the suitability of wastewater and land for wastewater irrigation application.

Three basic study components need to be addressed for sites where irrigation with municipal wastewater is proposed or practiced in Alberta:

- Characterization of wastewater quality to be used for irrigation (SECTION 2);
- Classification of the soils and lands onto which the irrigation wastewater will be applied (SECTION 3); and
- Specific design and management factors that promote long-term project viability (SECTION 4).

1.2 Municipal Wastewater Treatment

Municipal wastewater, which is 99% liquid, consists of suspended and dissolved solids, both organic and inorganic, and include large numbers of microorganisms. Wastewater treatment is provided to minimize the detrimental effect to the receiving environment, by achieving the following:

- removal of any floating matter and grit;
- reduction of suspended solids, oil and grease;

- reduction of dissolved organic matter and nutrients; and
- reduction of microorganisms.

In selecting the type of wastewater treatment process, a best practicable treatment approach is utilized whereby the effluent limits are based on the use of established and proven treatment technologies. Wastewater lagoons, activated sludge process, and rotating biological contactors are examples of systems allowed for municipal wastewater treatment in Alberta.

The treated effluent may then be discharged to either land or water. Methods of land application for the treatment and/or disposal of wastewaters generally include irrigation, high rate irrigation, rapid infiltration, and wet lands disposal. This guideline addresses only those issues relevant to the applications of treated wastewater to land by conventional irrigation practices.

1.3 Irrigation as a Municipal Wastewater Disposal Option

Treated municipal effluent does not always meet a quality standard that would enable its unrestricted discharge to the receiving environment. For land application, concerns still remain with respect to elevated concentrations of soluble salts, nutrients and microbiological quality of the treated effluent.

The major difference between municipal wastewater and "high quality irrigation water sources" is the higher concentration of living and nonliving organic material, nitrogen, phosphorus, and in some instances, higher sodium and salt levels in the municipal wastewater. Low concentration of grease, oil, detergents, and certain metals may also be present, but these are generally at concentrations that do not adversely impact crops and/or the land if applied through irrigation at rates compatible with a crops seasonal water deficit need.

Irrigation with municipal wastewater is a suitable disposal option in all regions of Alberta where additional moisture can be effectively utilized for improved crop production. Wastewater loading is to be based on the consumptive water use of the crop being grown. This loading, however, must also consider seasonal moisture deficiencies, system application efficiencies, and additional considerations related to annual soil leaching and crop nutrient utilization factors. The primary objective should be enhancement of crop production. The root zone of productive soils can often serve as one of the most active media for the decomposition, immobilization, or utilization of wastes. Considering these active processes in the topsoil, wastewater can often be safely released to land at water quality standards less restrictive than those that would apply to a surface water release option. Further, with the added benefits currently applied to waste re-utilization processes and water conservation practices, wastewater irrigation is considered an attractive waste disposal option.

2.0 ASSESSMENT OF MUNICIPAL EFFLUENT QUALITY FOR WASTEWATER IRRIGATION DEVELOPMENT

2.1 Wastewater Quality Characterization

As water quality standards for municipal wastewater discharging to surface water bodies become more stringent, the associated treatment costs correspondingly escalate. Irrigation is therefore becoming a more desired alternative for wastewater disposal for many communities. However, since different water quality variables need to be considered when evaluating wastewater effluents as a potential irrigation water source than those considered for its direct discharge into a receiving stream, a specific set of wastewater quality reporting requirements must be outlined and defined. In this overall treatise it is therefore important to first evaluate restrictions that may apply to the use of standard sources of irrigation water and then consider what supplemental evaluations would apply to wastewater irrigation use.

2.1.1 Natural Irrigation Water Quality Characterization

The use of waters for irrigation application, in Alberta, normally involve evaluation of the following water quality parameters[2]:

- ***Electrical conductivity (EC)***: is a reliable indicator of the total dissolved solids (salts) content of the water. The addition of irrigation water to soils adds to the concentration of salt in the soil. Concentration of these salts will result in an increase in osmotic potential in the soil solution interfering with extraction of water by the plants. Toxic effects may also result with an increase in salinity. EC is measured in dS m^{-1}. For specific values on acceptable EC levels in waters used for irrigation, refer to Table 1 that follows.

- ***Sodium Adsorption Ratio (SAR):*** is an indicator of the sodium hazard of water. Excess sodium in relation to calcium and magnesium concentrations in soils destroys soil structure that reduces permeability of the soil to water and air. Sodium may be toxic to some crops.

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$$ for concentrations in me/L AND $$SAR = \frac{Na^+}{\sqrt{Ca^{2+} + Mg^{2+}}}$$ for concentrations in mmoles/L

Cations are expressed in mequivalent of charge per litre or mmoles of charge per litre.

For specific values on acceptable SAR levels in waters used for irrigation, refer to Table 1.

- ***Boron (B):*** is very toxic to most crops at very low levels. In Alberta, however, excess natural boron in soils and water has not been a problem. Acceptable boron concentrations for agricultural use are included in the applicable Canadian Water Quality Guidelines[3], (Canadian Council of Ministers of the Environment 1999).

- ***Bicarbonate (HCO_3):*** is considered hazardous when concentrations are excessive in some areas and not in others. Waters of high bicarbonate concentrations have been used for many years with no adverse effects in Alberta. Acceptable bicarbonate concentrations for agricultural use are included in the applicable Canadian Water Quality Guidelines[3], published by CCME 1999.

For further information on any other chemical parameters that may impact irrigation suitability from natural water sources, reference should be made to the applicable Canadian Water Quality Guidelines[3], 1999.

In light of the preceding factors, only two parameters, SAR and EC are normally of concern when irrigating with most available water sources in Alberta. The limits for these parameters are as follows:

TABLE 1. Irrigation Water Quality Standards

	Safe	Possibly Safe	Hazardous
EC dS m^{-1}	< 1.0	1.0 - 2.5	> 2.5
SAR	< 4	4 - 9	> 9

The limits under the heading "Safe" are considered safe for all conditions. The "Possibly Safe" limits are considered safe for some conditions. Decisions should be based on the advice of a specialist. The "Hazardous" limits are considered unsuitable for almost all conditions.

Conditions to be assessed when dealing with waters that are "Possibly Safe" are as follows:

- Climate of the area — The deficit dictates the amount of water applied and consequently the amount of salt applied.
- Crops — Crops with high consumptive use require more irrigation water which again results in higher salt applications.
- Irrigation Practices — Light, frequent irrigation results in less leaching than less frequent water applications. Light, frequent irrigation results in more evaporation. Fall irrigation results in increased leaching.

- Internal drainage — Good internal drainage facilitates rapid leaching of salts out of the root zone.

System designs for irrigation with possibly safe water quality require specific investigation and the services of a specialist.

2.1.2 Comprehensive Wastewater Characterization

In contrast with fresh irrigation water, municipal wastewater has additional health and environmental factors that need to be considered to ensure no detrimental impacts occur from its use. Due to the origin, variety and often changing quality of wastewater generated by municipalities, it is imperative that municipal wastewaters be periodically tested for a much wider range of water quality parameters than is currently necessary for irrigation with fresh waters. A comprehensive characterization of the wastewater is necessary as part of the initial wastewater irrigation application process and subsequently as may be specified by Alberta Environment in the associated waste treatment facility renewal approval or authorizations. Annual monitoring of a number of key biological and chemical indicator parameters, both prior to and subsequent to any wastewater irrigation, should also be performed. The comprehensive wastewater quality characterization requirements and the annual wastewater quality monitoring requirements are discussed further in subsequent sections that follow.

The comprehensive characterization of wastewater quality provides a means to ensure a basic level of irrigation quality control. It also provides useful baseline information to evaluate impacts from future irrigation. These impacts may relate to changes that occur in community water sources, waste treatment processes, community size, and community or industrial discharge loadings. In addition, the wastewater quality characterization process may also provide an opportunity for community planners and engineering consultants to better evaluate the effectiveness of the treatment process and its ability to eliminate harmful constituents that could normally restrict the potential for irrigation use. The requirement of a comprehensive testing analysis in the initial application may enable future analytical testing requirements to be less onerous while still ensuring adequate protection of human health and the environment.

2.1.2.1 General Health Related Aspects

Biological assessment of municipal wastewater is obtained by means of biological counts performed on the wastewater prior to or on release. Potential human pathogens of concern found in domestic wastewater may be grouped into four categories (Englebrecht 1978[4]; Parsons et al 1975[5], National Research Council: 1996[6]), as follows:

- Bacteria (Salmonella, Shigella, Mycobacterium, Klebsiella, Clostridium)
- Protozoan parasites (Entamoeba, Giardia, Trichomonas)
- Helminth parasites (Ascaris, Toxacara, Taenia, Trichuris, Enterobius)
- Viruses (Picornaviruses, Adenoviruses, Rotaviruses)

The types and numbers of pathogenic organisms in wastewater depend on the nature of the wastewater being treated and the type of wastewater treatment. Wastewater organisms such as bacteria and viruses that are adsorbed to particulate matter tend to co-precipitate during settling phases of sewage treatment and, are thereby partly removed as solids from the water phase (Moore et al 1975[7]). Similarly, encysted and egg stages of parasites, with specific gravities 1.06 to 1.2 (Englebrecht 1978[4]), are effectively removed from the liquid wastewater during the settling phases of wastewater treatment process. The use of trickling filters, activated sludge systems, and effluent disinfection are additional treatment processes traditionally used to further reduce certain pathogenic organisms in wastewater. However, there is no single wastewater treatment process, which will remove all pathogenic microorganisms. Many potentially disease-causing microorganisms will therefore continue to be present in municipal wastewater. The types and amounts of these microorganisms will vary greatly with the treatment process or combination of processes utilized. Despite their presence, the potential health hazard associated with utilizing wastewater for irrigation can be minimized by adopting certain precautions and procedures.

For wastewater irrigation to be authorized in Alberta, the minimum treatment requirement is primary treatment followed by seven-month storage. Primary treatment is considered as a level of treatment rather than as a specific treatment process. When combined with storage facilities, primary treatment may be obtained by the use of anaerobic cells in series or at an enhanced level of primary treatment through specially engineered aeration lagoons. The majority of potentially harmful microorganisms are killed over a period of time by exposure to strong sunlight, high temperatures, and dry weather. Disinfection of wastewater prior to land application shall be required where warranted by public health concerns, e.g. golf courses, parks, etc. Bacteriological quality shall meet the standards outlined in Table 3.3 in the AENV document Standards and Guidelines for Municipal Waterworks, Wastewater and Storm Drainage Systems[8].

The timing of effluent irrigation with respect to harvesting crops and grazing livestock is also a factor that must be addressed; for further details reference should be made to Section 4 of this Guideline.

Wastewater irrigation of certain crops that may be eaten raw or which have a leaf structure that can harbour microorganisms, has also been prohibited in Alberta. For further discussion of health related issues concerning use of wastewater for irrigation in other provinces and countries, refer to the publication, Health Aspects of Sewage Effluent Irrigation 1975[5] and Use of Reclaimed Water and Sludge in Food Crop Production Chapter 5, Public Health Concerns about Infectious Disease Agents, National Research Council 1996[6].

Assessment of bacteriological constituents for the comprehensive wastewater characterization requires only the testing of total and fecal Coliforms. Additional testing for other bacteriological parameters has not been found to be necessary in Alberta as adoption of a best practicable treatment approach requiring primary treatment, storage, and various crop restrictions before irrigation, has proven appropriate in protecting the public from any adverse exposures to these particular constituents.

2.1.2.2 Other Water Quality Aspects

Other water quality aspects to be included in the comprehensive wastewater characterization assessment prior to the development of a wastewater irrigation system are included in the sections to follow.

General Chemical Parameters

The general parameters are those that are analyzed to assess the effectiveness of the wastewater treatment process and to evaluate variability in the quality of the wastewater prior to its release to the environment. They also represent water quality values that, if exceeded, can often restrict treated wastewater sources from being considered for irrigation purposes.

- *Biochemical Oxygen Demand (BOD)* typically ranges from 10 to 20 mg/L for most municipal wastewaters. Values below 100 mg/L pose no restriction to irrigation use.

- *Total Suspended Solids (TSS)* typically ranges from 10 to 20 mg/L for most municipal wastewaters. Values below 100 mg/L pose no restriction to irrigation use.

- *Chemical Oxygen Demand (COD)* typically ranges from 25 to 50 mg/L for most municipal wastewaters. Values below 150 mg/L pose no restriction to irrigation use.

- *pH* typically ranges from 6.5 to 8.5 for most municipal wastewaters. These values are comparable to most natural surface waters and are considered to pose no restriction to irrigation use. A continued long-term use of waters outside this pH range could eventually alter naturally occurring pH levels in surface soils to which they are applied and therefore could possibly lead to micro nutrient imbalances and potential future crop production and fertility problems.

- *Electrical Conductivity (EC)* these values range widely within municipal wastewater and like some natural water sources exceed levels that would be recommended for irrigation.

Those municipal wastewaters with EC values less than 1.0 dS/m are considered of good quality and should pose no problems for irrigation use, unless the sodium adsorption ratio (SAR) of the wastewater is greater than 4.

Municipal wastewaters found to have EC values between 1.0 and 2.5 dS/m are considered marginal for irrigation and are usually restricted to use on land with favourable internal drainage properties. Crops normally grown under irrigation with such municipal wastewater would not be impacted significantly. For situations where wastewater of this quality is utilized for irrigation on a regular ongoing basis, supplemental approval conditions, requesting the periodic testing and reporting of salinity levels for lands being irrigated, would most likely apply. Results from such testing should be reported to AENV if:

- complaints of adverse impacts to the irrigated lands have been raised; or
- an application for approval renewal was being processed and concerns over deteriorating crop conditions were an issue.

Provision for periodic salt leaching is often advisable when considering wastewater irrigation with water in this EC range.

Wastewaters with EC values exceeding 2.5 dS/m must not be used for irrigation purposes. If other sources of high quality irrigation water are available, possible blending of the two water sources could be accomplished but is not a practice that is promoted by Alberta Environment. Authorization for a project, utilizing water blending, would require prior approval from AENV. Any such application would be restricted to a low volume discharge situation and require supplemental monitoring and reporting to be compiled on a regular basis.

It may be noted that EC values are often high in communities that utilize groundwater as a water supply source. Improving the quality of water supplies for these communities or adopting an alternate water supply source can lead to improvement in final wastewater EC levels for these communities and possibly improve its suitability for irrigation.

- *Sodium Adsorption Ratios (SAR)* values can vary widely within municipal wastewater treatment facilities and like many natural water sources can often occur at levels that restrict their use for irrigation applications. Since adverse effects from high SAR are also dependent on the associated EC levels of the wastewater, one should be aware of this interrelationship when evaluating SAR.

As a general guide wastewater having SAR values less than 4 pose no problem for irrigation use.

Municipal wastewaters with SAR values ranging between 4 and 9 are considered marginal for irrigation and must include careful management to avoid potential damage to the landbase or reduced crop productivity. Applying wastewater of this quality can be particularly damaging on very fine textured soils or in situations where EC values of the wastewater are less than 1 dS/m. Occasional calcium-nitrate or gypsum applications may be helpful as a supplemental management practice on lands receiving irrigation

applications of this quality for long periods of time. For situations where marginal municipal wastewater quality is utilized for irrigation, supplemental approval conditions, including periodic testing would apply. Results from such testing should be reported to AENV if:

- complaints of adverse impacts to the irrigated lands have been raised; or

- an application for approval renewal was being processed and concerns of deteriorating soil quality or reduced crop productivity were an identified issue.

Wastewater with SAR values exceeding 9 should not be used for irrigation.

Communities using ion-exchange process for water softening can significantly increase SAR values in the wastewater. Hence, careful and regular monitoring of SAR levels within systems where water softeners are used is important.

<u>Nutrients</u>

One of the main advantages of using wastewater irrigation is that it can often enhance the fertility of the lands to which it is applied. This can add considerably to potential crop yield and therefore the associated agricultural resource value. Nutrient loading rates, while significant, are seldom at levels that would present a concern when using municipal wastewater for irrigation. Most nutrient levels are well within the range that can be assimilated by plants if the wastewater is applied at a rate and frequency that conforms to active crop growth. Potential contamination of groundwater would only be a concern under extremely shallow groundwater levels, unsuitable soil conditions, or gross mismanagement of the applied wastewater. Since all these factors are carefully considered as part of the guidelines, potential contamination of the groundwater should not present a concern.

The following nutrients should be analyzed and reported as part of the comprehensive wastewater quality characterization process:

- Nitrogen can be evaluated in a number of different forms. Evaluation of nitrogen by analyzing for NO_3^- N, NH_4^-N, NO_2^-N, and TKN should be conducted. The typical range for total nitrogen of most municipal wastewater is 10 to 20 mg/L. This means that if 30 cm of wastewater were applied, an N loading of 30 to 60 kg/ha/yr. would be applied to the landbase. Providing wastewater is not applied in quantities that exceed the field moisture capacity during periods of wastewater applications, and is applied during the active crop growing season, such loadings can be easily assimilated by the growing crop without harmful health or environmental concerns developing.

- Phosphorus is to be evaluated as total dissolved phosphorus. The typical range of total dissolved phosphorus in municipal wastewater is between 2 and 6 mg/L. If 30 cm of wastewater were applied, this would translate to a P loading of 6 to 18 kg/ha/yr. Since these levels are considered to be reasonably low and phosphorus is effectively immobilized in most soils at shallow depths, the potential for adverse impacts on groundwater quality is remote. Care must be exercised, however,

to ensure wastewater applications are applied at rates that do not exceed the infiltration capacity of the soils as high phosphorus levels in surface runoff and erosion sediments can create significant environmental concern if washed into neighbouring lakes, streams or other surface water bodies.

- Potassium is another major nutrient present in wastewater of value for crop production that should be evaluated. The typical range for potassium in most municipal wastewaters is 5 to 40 mg/L. If 30 cm of wastewater were applied this would translate to a K loading of 15 to 120 kg/ha/yr. Such levels are readily assimilated by the actively growing crops and are thus not considered to be of an environmental or health risk.

Table 2 prepared from data developed by Alberta Agriculture, Food and Rural Development (AAFRD), provides some typical nutrient removal rates for crops commonly grown under irrigation in Alberta as noted.

TABLE 2. Nutrients uptake by various irrigated crops in southern Alberta[z].

Crop	Yield, kg ha^{-1}	Nutrient removal, kg ha^{-1} (% of yield)[y]		
		N	P_2O_5	K_2O
Spring wheat	5400	190 (3.5)	65 (1.2)	145 (2.7)
Barley	6500	180 (2.8)	65 (1.0)	190 (2.9)
Canola	4000	200 (5.0)	60 (1.5)	130 (3.2)
Flax	2800	130 (4.6)	45 (1.6)	90 (3.2)
Corn	6300	150 (2.4)	70 (1.1)	145 (2.3)
Sugar beets	45000	195 (0.4)	45 (0.1)	280 (0.6)
Potatoes	34000	170 (0.5)	75 (0.2)	230 (0.7)
Alfalfa	9000	260 (2.9)	45 (0.5)	210 (2.3)
Peas	4200	220 (5.2)	55 (1.3)	150 (3.6)

[z] Source: R. H. McKenzie, Agronomy Unit, Plant Industry Division, Alberta Agriculture, Food and Rural Development, Lethbridge, Alberta.

[y] All values are for seed and straw for grains and tuber or beet plus above ground matter for potatoes and sugar beets; $P = P_2O_5 \times 0.437$, $K = K_2O \times 0.83$.

Major Cations and Anions

The wastewater should be analyzed and reported for the following cations and anions in the required comprehensive wastewater characterization:

Calcium (Ca) mg/L	Magnesium (Mg) mg/L	Sodium (Na) mg/L
Carbonate (CO_3) mg/L	Bicarbonate (HCO_3) mg/L	Alkalinity, total ($CaCO_3$) mg/L
Fluoride (F) mg/L	Sulphate (SO_4) mg/L	Chloride (Cl) mg/L

Metals

Uptake of harmful amounts of toxic heavy metals by plants is not considered a potential risk in use of municipal wastewater, as most metals are removed from the wastewater during the primary treatment process. However, as a precautionary measure, all wastewater should be initially tested for the metals in Table 3 to ensure levels are below recommended CCME water quality standards prior to granting authorization for irrigation application.

Since collection of this information is intended more as a general wastewater quality characterization inventory rather than for purposes of assessing irrigation water quality limits, specific values will likely not be exceeded for most municipal wastewater tested.

In addition, a careful evaluation of any industrial discharges into the municipal system and their potential impact on overall wastewater quality must also be addressed. If, due to the nature of these industrial activities, concerns relating to any other chemicals become evident, then these chemicals should also be added to the comprehensive list of suggested chemical parameters for wastewater characterization.

TABLE 3. Canadian Water Quality Guidelines for the Protection of Agricultural Water Uses

Parameter	Concentration (µg/L)
Aluminium	5000
Arsenic	100
Boron	500-6000
Cadmium	5.1
Chromium - Trivalent Cr (iii) - Hexavalent Cr (vi)	 4.9 8.0
Cobalt	50
Copper	200-1000
Fluoride	1000
Iron	5000
Lead	200
Lithium	2500
Manganese	200
Molybdenum	10-50
Nickel	200
Selenium	20-50
Uranium	10
Vanadium	100
Zinc	1000-5000

(Limits are adopted from the Summary Table, Canadian Environmental Quality Guidelines, Canadian Council of Minister of the Environment, 1999)

2.1.3 Annual Wastewater Quality Monitoring Requirements

Wastewater must also be analyzed and results reported annually for certain water quality parameters, both prior to and on completion of each irrigation application event. This monitoring requirement is in addition to the comprehensive wastewater characterization outlined in section 2.1.2. For annual testing purposes the wastewater should be sampled at the pipe inlet of the irrigation distribution equipment. The treated effluent quality for wastewater irrigation shall meet the standards specified in Table 4.

TABLE 4. Treated Effluent Quality Standards for Wastewater Irrigation

Parameter	Standard	Type of Sample	Comments
Total Coliform*	<1000/100 mL	Grab	Geometric mean of weekly samples (if storage is provided as part of the treatment) or daily samples (if storage is not provided), in a calendar month
Fecal Coliform*	<200/100 mL	Grab	Geometric mean of weekly samples (if storage is provided as part of the treatment) or daily samples (if storage is not provided), in a calendar month
CBOD	<100 mg/L	Grab/composite**	Samples collected twice annually, prior to and on completion of a major irrigation event
COD	<150 mg/L	Grab/composite**	Samples collected twice annually, prior to and on completion of a major irrigation event
TSS	<100 mg/L	Grab/composite**	Samples collected twice annually, prior to and on completion of a major irrigation event
EC	<1.0 dS/m for unrestricted use 1.0 - 2.5 dS/m for restricted use >2.5 dS/m unacceptable	Grab/composite**	Samples collected twice annually, prior to and on completion of a major irrigation event
SAR	<4 for unrestricted use 4-9 for restricted use when EC >1.0 dS/m >9 unacceptable	Grab/composite**	Samples collected twice annually, prior to and on completion of a major irrigation event
pH	6.5 to 8.5	Grab/composite**	Samples collected twice annually, prior to and on completion of a major irrigation event

* For golf courses and parks only.

** Grab sample would suffice if storage is provided; Composite sample is required if storage is not provided.

CBOD - Carbonaceous Biochemical Oxygen Demand
COD - Chemical Oxygen Demand
TSS - Total Suspended Solids
EC - Electrical Conductivity
SAR - Sodium Adsorption Ratio

3.0 ASSESSMENT OF LAND SUITABILITY FOR PROPOSED WASTEWATER IRRIGATION DEVELOPMENT

Land classification and other relevant soil, climate, and groundwater assessment activities are generally performed after completing the comprehensive wastewater characterization assessment, and results of the wastewater characterization have shown that the wastewater is suitable for irrigation.

Careful assessment and characterization of the landbase including associated soil, groundwater, and other crop related inputs are required prior to proceeding with actual design of the wastewater irrigation system. A site is classed as suitable for wastewater application only if it is found to possess soil, climatic, and physical characteristics that enable effective utilization of the wastewater applied without causing future damage to the landbase or to the underlying groundwater. Site conditions must also be such that they effectively restrict any detrimental offsite movement of the wastewater through either leaching, groundwater migration, surface runoff, or drift from irrigation spray. The following sections outline land classification, soil, and other testing requirements that must be addressed prior to actual development of an applicable wastewater irrigation system design and issuance of the authorized approval.

3.1 Land Suitability for Irrigation

Before major irrigation development can proceed in Alberta, the lands to be irrigated must first be classified by an accredited land irrigation classifier and the classification assessment reviewed and registered with Alberta Agriculture, Food and Rural Development (AAFRD), in Lethbridge. This land irrigation classification requirement also applies to all lands intended for wastewater irrigation purposes.

Further, the minimum rating with which land must comply to be suitable for receiving wastewater shall be a Land Class 3 defined by Standards For The Classification of Land For Irrigation in the Province of Alberta (AAFRD, 1999[9]) and the Procedures Manual for Land Classification For Irrigation in Alberta (Alberta Agriculture, 1992[2]). The level of investigative detail shall be a Level II intensity (Alberta Agriculture, 1992[2], and AAFRD, 1999[9]) and must be completed by an accredited land classification consultant, reviewed by Alberta Agriculture, Food and Rural Development, and then submitted to Alberta Environment along with the additional soil investigation requirements specified in Section 3.1.1. The identified land suitability conditions shall apply to all wastewater irrigation development projects unless authorized otherwise in writing by Alberta Environment.

All the designated irrigation areas including the irrigation classification ratio and corresponding soil sampling locations must be clearly identified and mapped and this information supplied to AAFRD in Lethbridge for inputting to their data base.

For purposes of the AAFRD review, the following information shall be provided:

- a map showing the location of all soil sampling and description sites;
- a copy of all soil logs;
- a copy of soil chemical and physical analysis completed for the classification;

- a legible soil/land class map that shows the land class and soil description of each land class unit (Alberta Agriculture 1992; AAFRD 1999);
- a drafted land classification map at a scale of 1:5000 showing the land class symbol, drainability and limitations for each unit classified; and
- a remark sheet or report that accompanies the land classification map. The typed report shall briefly describe each land class unit with regard to the type of soils, soil texture, irrigation suitability, suitability for gravity or sprinkler irrigation development, the limitations of the irrigable units and reasons why nonirrigable units are rated nonirrigable. A statistical summary table that shows the following, where applicable, shall also be included: total irrigable acres; total nonirrigable acres; right-of-way and easement acres; not investigated acres; and acres of farmsteads or other physical features that are present.

Municipal wastewaters have much higher nitrate levels than other irrigation water sources in Alberta. It is therefore necessary to further restrict wastewater application on lands where the natural water table is less than 2m below ground surface and/or impermeable bedrock or other geological barriers exist at less than 4m below ground surface.

The following soil and site characterization details must also be collected and reported, in addition to completing the required land classification designations and mapping.

3.1.1 Soil

Soil-related information must be provided for each individual soil unit delineated within the area of proposed irrigation where the size of that unit is 4ha or greater and is rated as suitable for irrigation development (i.e. Land Class 3 or better). Therefore, if a land area was extremely complex, 16 separate soil units could exist per quarter section of land being classified, thus requiring soil sampling at 16 separate locations within the quarter section. In the other situation, where the mapped area is extremely uniform and only one mapping unit occupies the entire quarter section, a minimum sampling at four separate locations would be required per quarter section of land classified for potential irrigation development. Any classification unit that was mapped as a soil complex where 30% or more of that unit consists of nonirrigable soils, solonetzic, saline, gleyed, or gleysolic, the identified unit would be considered not suitable for wastewater irrigation development. The boundaries of the specific quarter section in which any sampling is conducted and the boundaries of each land classification unit designated, must be clearly illustrated and included with the mapping of the sampling site locations. The scale of map used to portray this information must be at a 1:5000 scale.

The soil sampling to be conducted for each individual soil sampling site location must be conducted in the following manner:

1. Soil samples are to be collected from the following depth intervals, at each sampling location:

   0 to 15 cm   15 to 25 cm   25 to 50 cm   50 to 100 cm   100 to 150 cm

2. Each soil sample is to be at least 1 kilogram in weight. The samples must be representative of the soil conditions over the depth interval for which they were collected. Each sample is to be bagged separately in a plastic bag and labelled according to the depth and location at which the sample was taken.

3. In addition to collecting the soil samples, the depth of the groundwater table below ground surface at each sample site location should be denoted. To accomplish this, the hole being drilled to obtain the soil samples should be extended to a depth of 4 m. An appropriately sized PVC standpipe that is slotted over the bottom 2 m and fitted with a slip cap at its base should be placed down the hole. After allowing appropriate time for water to stabilize in the constructed well, the standpipe should be checked. If freestanding water is noted, the depth below ground surface at which the water was encountered should be recorded along with the date of the observation. If the pipe remains dry, this should be noted along with the date the observation was made and the length of time the site was allowed to stabilize before the attempted measurement was taken. Once the monitoring is complete, the pipe should be removed and the hole backfilled according to water well drilling regulations of AENV. If the presence of bedrock or a hardpan is noted or prevents drilling to a depth of 4 m at any location, this is to be recorded along with the measurement of depth below ground surface at which the drilling stopped or the restriction encountered.

4. The soil samples from each sampling site location shall then be forwarded to a laboratory for the following analyses:

Physical Soil Parameters

A soil particle size distribution analysis shall be determined using the hydrometer method in Methods of Soil Analysis, Part 1, Agronomy #9 (American Society of Agronomy 1965[10]). This analysis should be conducted for all soil samples collected. Results of the analysis should indicate the percentage of sand, silt, and clay and denote the appropriate textural classification as per the Canadian System of Soil Classification[11]. The available soil moisture holding capacity should be determined for each soil sample tested based on Table 3.3, page 17 in the Procedures Manual for Land Classification For Irrigation in Alberta (Alberta Agriculture, 1992[2]).

Soil texture information can be used to infer associated soil infiltration capacity or percolation rates of individual land units classified suitable for irrigation. For purposes of irrigation with wastewater each soil unit shall be assigned a soil infiltration or percolating rating based on its soil profile and textural characteristic. This requirement is necessary to ensure that appropriate sprinkler nozzle sizes and operating runtimes are incorporated into the design of the irrigation system to avoid concerns of over application of wastewater and associated problems of surface runoff, uneven wastewater distribution and surface water ponding. Soil textures with identified percolation rates between 2.0 and 24 minutes/cm are considered most suitable for wastewater irrigation. The soil textural evaluations, available moisture calculations, and percolation / infiltration values will ultimately serve to:

- assist with evaluation of system design; and

- provide a basis for establishing acceptable limits in the regulation of irrigation rates, frequencies, and application duration.

Chemical Soil Parameters
Soil samples taken from the 0 to 15, 15 to 25, and 25 to 50 cm depths are to be analyzed for soil pH as a saturated paste extract; soil EC dS/m as measured on saturated paste extract with conductivity cell; soil SAR as calculated from soluble ions (Ca, Mg, & Na) in paste extract; major cations (Ca, Mg, K, Na) mg/L as measured in a saturated paste extract using ICP-AES or AA; major anions (Cl, NO_3, SO_4) mg/L as measured on saturated paste extract using colorimetric measurement Flow Injection Autoanalyzer (FIA) or Ion Chromatography (IC); plant available nitrogen should be assessed on a KCL extract (Carter, M.R. 1993)[12]; with the NO_3, and NH_4 analyzed by any suitable technique but to be reported as μg N/g soil; and plant available phosphorus should be extracted using a Kelowna or Modified Kelowna extraction method and a suitable laboratory method of analyzing PO_4.P content in the extract (Carter, M.R.) with the analytical results to be expressed as μgP/g.

Soil samples taken from the 50 to 100 cm and 100 to 150 cm depths should be analyzed for soil pH on a saturated paste extract, soil EC and soil SAR by the same methods of analysis as used for the shallower sampling depths.

The chemical soil testing methods suggested above are intended as basic direction to those involved collecting the soils in order to advise the individual laboratories of the types of analysis to be conducted. If alternate analytical procedures or methods are adopted that can ensure comparable results, and provided appropriate justification and protocols supporting the use of these alternate methods are provided, such substitute methods may also be acceptable.

3.1.2 Topography

The topography is to be classified as to its suitability for wastewater irrigation according to Chapter 4 of the Procedures Manual For Land Classification For Irrigation (Alberta Agriculture, 1992[2]) and the Standards for the Classification of Land for Irrigation in the Province of Alberta (AAFRD 1999[9]). The topography at each site is also to be mapped. This topographic mapping should be provided at a level of detail not less than a scale of 1:10,000 and a contour interval of 0.5m. The information should be gathered either from a topographic survey of the land parcel or from a suitable scaled orthophoto or photogrammetric mapping of the property. This mapping must reference appropriate section and quarter section boundaries, wastewater irrigation development boundaries, and soil test and groundwater test site locations. Inclusion of recent stereoscopic air photo coverage at a 1:10,000 scale would be advisable, but is not a requirement.

3.2 Other Requirements

Other information in the initial site assessment process must include:

- Location and mapping of any surface watercourses, water bodies, or domestic wells located on or within 150 m of the wastewater irrigation development site.
- Location and mapping of any residential dwelling on or within 150 m of the wastewater development site.
- Location and mapping of all public roads, highways, or other public corridors on or within 30 m of the wastewater development site.

These site-specific requirements are intended to provide baseline information on all sites to be developed for wastewater irrigation purposes. The knowledge is intended to assist in evaluating potential impacts of long-term wastewater irrigation on the landbase, over time.

4.0 ASSESSMENT OF SYSTEM DESIGN NEEDS FOR PROPOSED WASTEWATER IRRIGATION DEVELOPMENT

Wastewater irrigation system design is undertaken once water quality assessment and land suitability assessment are affirmed. The design integrates wastewater quality with landbase limitations and restrictions that relate to cropping, climate, application, and public acceptance issues. The overall design includes an account of the following:

4.1 Climate

There are a number of climate factors that must be considered to ensure an effective wastewater irrigation system design. These factors are defined as follows:

- Wastewater irrigation applications are restricted to the period of May 1st to September 30th. Also, wastewater application (during this period of May 1st to September 30th) must not occur if temperatures drop below freezing, if wind speeds are in excess of 30 km/hr, or during periods of intense or prolonged precipitation. Storage must be provided for the seven-month period when wastewater irrigation application is not authorized.

- Wastewater irrigation is a suitable disposal option only in regions where the additional moisture applied can be utilized for improved crop production. Seasonal mean precipitation, evapotranspiration and seasonal crop moisture demands must therefore be established for the period between May 1st and September 30th or for the irrigation period authorized and be applicable to the geographical area of the specific project. These requirements will be necessary to determine the landbase required to effectively dispose of the annual volumes of community wastewater available for discharge. Sufficient land to handle this anticipated flow must be obtained. Alberta subscribes to an almost complete utilization of nutrients and about 85% utilization of water. Since annual values will vary from year to year, design must allow for either a 25% wastewater storage carry over or provision for an occasional expansion in irrigation system and landbase design in order to accommodate the lower wastewater irrigation discharge allotments required during wet years. Provision for supplemental irrigation sources in dry periods may also be considered.

4.2 Land Area

There are a number of land-related factors relevant to irrigation system design that must be considered. These factors are defined as follows:

- Specific irrigation design features must be provided that will avoid application of irrigation wastewater to any non-irrigable land areas (greater than 15 percent of the area to be irrigated).

- The amount of land and equipment required will depend upon the mean annual consumptive use of water by plants, natural precipitation from April through September, an irrigation efficiency factor, and an appropriate leaching requirement. If no provisions are provided for extra wastewater storage during abnormally wet years, additional land areas and equipment will be required to meet these needs.

- The land area to be accumulated must also allow for any buffer zones or setback limits that apply on or around land areas where wastewater irrigation is to be undertaken. Set backs and buffer zones that will apply include:

  i) A buffer zone of 15 m shall be provided between the irrigated land and any other adjacent property unless permission is received from the adjacent owner(s) to lessen this distance.
  ii) A minimum buffer zone of 60 m and preferred set back of 100 m shall be provided between the irrigated land and any occupied dwellings.
  iii) A setback zone of 30 m shall be provided between all irrigated land and either seasonal watercourses, public roads, railway lines, or water wells.
  iv) A minimum buffer zone of 30 m and preferred set back of 50 m shall be provided between the irrigated land and any surface water body including dugouts, irrigation canals, lakes, streams, rivers, and water reservoirs.

- In addition to the above consideration, the land area to be used for wastewater irrigation and storage cells shall be sufficiently large such that wastewater discharge will not occur during the following periods.

  i) Outside the growing season except if authorized for a fall irrigation.
  ii) During and for 30 days prior to the harvesting of crops.
  iii) During and for 30 days prior to grazing by dairy cattle.
  iv) During and for 7 days prior to pasturing by livestock other than dairy cattle.

- A plan illustrating the layout of the irrigation system designed to irrigate the site shall be provided. The plan must illustrate: the boundaries of the particular section(s) within which irrigation application will take place, the boundaries of the land area to which wastewater will be applied, the extra land area to be irrigated during wet seasons when above average mean seasonal precipitation occurs if design for extra lagoon storage is not provided and the actual orientation of irrigation equipment, sprinkler head sizing, operating pressures and overall irrigation system layout.

4.3 Application Loading Rates

The rate of wastewater application loading shall depend on individual crop moisture and nutrient uptake needs. These factors are defined as follows:

- Nitrogen is usually the only nutrient that may prove to be restricting in respect to the amount of municipal wastewater that may be applied in a given irrigation season. The amount of plant available nitrogen, based on amount of wastewater that is applied, should be calculated and noted as kg ha^{-1} yr^{-1}. As long as these rates do not exceed the annual crop nitrogen removal rates and an active crop-harvesting program exists no restrictions to the application of typical municipal wastewater should apply. Other major nutrients generally do not exceed annual crop uptake requirements and therefore do not pose a risk to water quality. To determine typical nutrient removal rates for common irrigated crops, in Alberta, reference should be made to Table 2 presented earlier in the guideline.

- Crop moisture requirements thus become the main determining factor in establishing acceptable wastewater irrigation application limits. Annual wastewater application amounts ultimately depend on the annual seasonal crop needs minus season rainfall. However, other factors such as: soil moisture holding capacity, soil infiltration rate, crop rooting depth, rate frequency and duration of irrigation event, irrigation system efficiency, and soil leaching requirements, will have a bearing on the efficiency of crop moisture utilization and therefore need to be evaluated as part of any irrigation system design. A local irrigation specialist or a qualified agricultural consulting firm should be consulted to ensure accurate assessments of these values for different locations within Alberta. The eventual design of the irrigation system must ensure effective uniform application of the wastewater and prevent any surface runoff or prolonged surface ponding to occur during application. The irrigation system must also be designed to avoid wastewater applications that exceed crop seasonal water deficit requirements and leaching demands. If natural precipitation during the irrigation off-season is not sufficient to enable leaching of excess salt accumulations, the irrigation system must account for an annual leaching factor of 10 percent. This being required to assist with flushing excess soluble salts below the crop root zone.

4.4 Crop Considerations

Only certain crops are deemed suitable for production on lands to be irrigated with municipal wastewater in Alberta. The current authorized crops include only forages, coarse grains, turf, and oil seeds. Any other crops to be considered must be first supported by scientific based studies that ensure there are no associated human health risks and that the applied moisture and nutrient loading can be appropriately utilized by the crop without surface runoff or excessive leaching.

4.5 Wastewater Storage Ponds

The design of any storage reservoir required to retain wastewater during the periods of restricted irrigation application must meet all design criteria presently in place for such facilities. In addition it is important to recognize climatic variations in sizing wastewater storage ponds. Allowances will need to be made in the design to accommodate the annual variations in climate. Three alternatives that can be considered for dealing with abnormally wet conditions are as follows:

- Land area in excess of that calculated for an average year could be obtained, along with the required additional irrigation equipment. In this situation, no additional storage above the normal safety provisions would be necessary in sizing the lagoon.

- Larger wastewater applications could be applied to the landbase than required by the crop. This could lead to concerns with potential groundwater contamination and groundwater mounding, which if allowed to occur frequently, could damage the site for future use. A supplemental groundwater monitoring and testing program would therefore be required at the site, if this particular option were considered. This option would only be considered for emergency situations where prior written notification of the need to over apply wastewater had been requested and was authorized by AENV. Frequent requests for such an authorization for over application would result in the need to develop an alternate means to deal with the issue.

- The storage reservoir could be overdesigned. This would allow excess wastewater from a wet year to be held over for use during an abnormally dry year. The additional storage should be determined based on variations in the mean annual precipitation of the area where the site is located.

5.0 SYSTEM OPERATION

Once the wastewater development project has been approved and constructed, an Approval to Operate is required before operation can proceed. The approval will spell out operating conditions and requirements for the system.

The municipality must be responsible for the proper operation of the irrigation project, even if someone other than the municipality is actually managing the system. Proper operation of the system is essential for longevity of the system, for a high degree of treatment and for high production. Although crop production is not the prime objective of the system, a vigorous crop growth is essential for utilization of water and nutrients.

Due to the great variation in waste concentration, soils, and climate, no attempt will be made to elaborate further on irrigation management. Specific operational requirements will be stated in the approval to operate.

6.0 REFERENCES

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